On website waterlog.info

Agricultural hydrology is the study of water balance components intervening in agricultural water management, especially in irrigation and drainage/

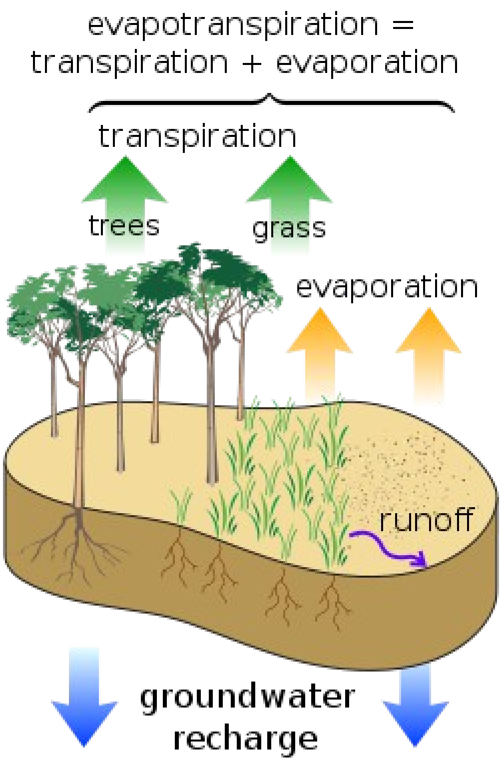


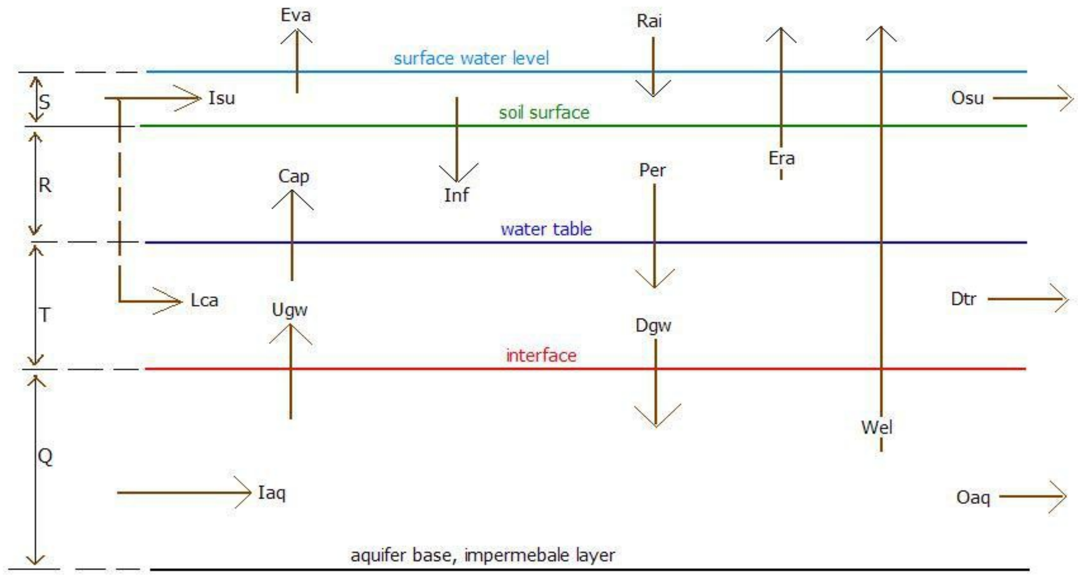
Illustration of some water balance components in the soil

Contents

Water balance components

The water balance components can be grouped into components corresponding to zones in a vertical cross-section in the soil forming reservoirs with inflow, outflow and storage of water:

1. the surface reservoir (*S*)
2. the root zone or unsaturated (vadose zone) (*R*) with mainly vertical flows
3. the aquifer (*Q*) with mainly horizontal flows
4. a transition zone (*T*) in which vertical and horizontal flows are converted



Water balance components in a vertical soil section

S = surface reservoir R = root zone or unsaturated (vadose) zone T = transition zone Q = aquifer

The general water balance reads:

- inflow = outflow + change of storage

and it is applicable to each of the reservoirs or a combination thereof.

In the following balances it is assumed that the water table is inside the transition zone.

If not, adjustments must be made.

Surface water balance

The incoming water balance components into the surface reservoir (*S*) are:

1. Rai - Vertically incoming water to the surface e.g.: precipitation (including snow), rainfall, sprinkler irrigation
2. Isu - Horizontally incoming surface water. This can consist of natural inundation or surface irrigation

The outgoing water balance components from the surface reservoir (*S*) are:

1. Eva - Evaporation from open water on the soil surface (see Penman equation)
2. Osu - Surface runoff (natural) or surface drainage (artificial)
3. Inf - Infiltration of water through the soil surface into the root zone

The *surface water balance* reads:

- Rai + Isu = Eva + Inf + Osu + Ws,

  where Ws is the change of water storage on top of the soil surface

Root zone water balance

The incoming water balance components into the root zone (*R*) are:

1. Inf - Infiltration of water through the soil surface into the root zone
2. Cap - Capillary rise of water from the transition zone

The outgoing water balance components from the surface reservoir (*R*) are:

1. Era - Actual evaporation or evapotranspiration from the root zone
2. Per - Percolation of water from the unsaturated root zone into the transition zone

The *root zone water balance* reads:

- Inf + Cap = Era + Per + Wr,

  where Wr is the change of water storage in the root zone

Transition zone water balance

The incoming water balance components into the transition zone (*T*) are:

1. Per - Percolation of water from the unsaturated root zone into the transition zone
2. Lca - Infiltration of water from river, canal or drainage systems into the transition zone, often referred to as deep seepage losses
3. Ugw - Vertically upward seepage of water from the aquifer into the saturated transition zone

The outgoing water balance components from the transition zone (*T*) are:

1. Cap - Capillary rise of water into the root zone
2. Dtr - Artificial horizontal subsurface drainage, see also Drainage system (agriculture)
3. Dgw - Vertically downward drainage of water from the saturated transition zone into the aquifer

The *water balance of the transition zone* reads:

- Per + Lca + Ugw = Cap + Dtr + Dgw + Wt,

  where Wt is the change of water storage in the transition zone noticeable as a change of the level of the water table.

Aquifer water balance

The incoming water balance components into the aquifer (*Q*) are:

1. Dgw - Vertically downward drainage of water from the saturated transition zone into the aquifer
2. Iaq - Horizontally incoming groundwater into the aquifer

The outgoing water balance components from the aquifer (*Q*) are:

1. Ugw - Vertically upward seepage of water from the aquifer into the saturated transition zone
2. Oaq - Horizontally outgoing groundwater from the aquifer
3. Wel - Discharge from (tube)wells placed in the aquifer

The *water balance of the aquifer* reads:

- Dgw + Iaq = Ugw + Wel + Oaq + Wq

where Wq is the change of water storage in the aquifer noticeable as a change of the artesian pressure.

Specific balances

Combined balances

Water balances can be made for a combination of two bordering vertical soil zones discerned, whereby the components constituting the inflow and outflow from one zone to the other will disappear.
In long term water balances (month, season, year), the storage terms are often negligible small. Omitting these leads to *steady state* or *equilibrium* water balances.

Combination of surface reservoir (*S*)and root zone (*R*) in steady state yields the **topsoil water balance** :

- Rai + Isu + Cap = Eva + Era + Osu + Per,

  where the linkage factor *Inf* has disappeared.

Combination of root zone (*R*) and transition zone (*T*) in steady state yields the **subsoil water balance** :

- Inf + Lca + Ugw = Era + Dtr + Dgw,

  where the linkage factors *Per* and *Cap* have disappeared.

Combination of transition zone (*T*) and aquifer (*Q*) in steady state yields the **geohydrologic water balance** :

- Per + Lca + Iaq = Cap + Dtr + Wel + Oaq,

  where the linkage factors *Ugw* and *Dgw* have disappeared.

Combining the uppermost three water balances in steady state gives the **agronomic water balance** :

- Rai + Isu + Lca + Ugw = Eva + Era + Osu + Dtr + Dgw,

  where the linkage factors *Inf*, *Per* and *Cap* have disappeared.

Combining all four water balances in steady state gives the **overall water balance** :

- Rai + Isu + Lca + Iaq = Eva + Era + Osu + Dtr + Wel + Oaq,

  where the linkage factors *Inf*, *Per*, *Cap*, *Ugw* and *Dgw* have disappeared.

Water table outside transition zone

When the water table is above the soil surface, the balances containing the components *Inf*, *Per*, *Cap* are not appropriate as they do not exist.

When the water table is inside the root zone, the balances containing the components *Per*, *Cap* are not appropriate as they do not exist.

When the water table is below the transition zone, only the *aquifer balance* is appropriate.

Reduced number of zones

Under specific conditions it may be that no aquifer, transition zone or root zone is present. Water balances can be made omitting the absent zones.

Net and excess values

Vertical hydrological components along the boundary between two zones with arrows in the same direction can be combined into *net values* .
For example : Npc = Per − Cap (net percolation), Ncp = Cap − Per (net capillary rise).

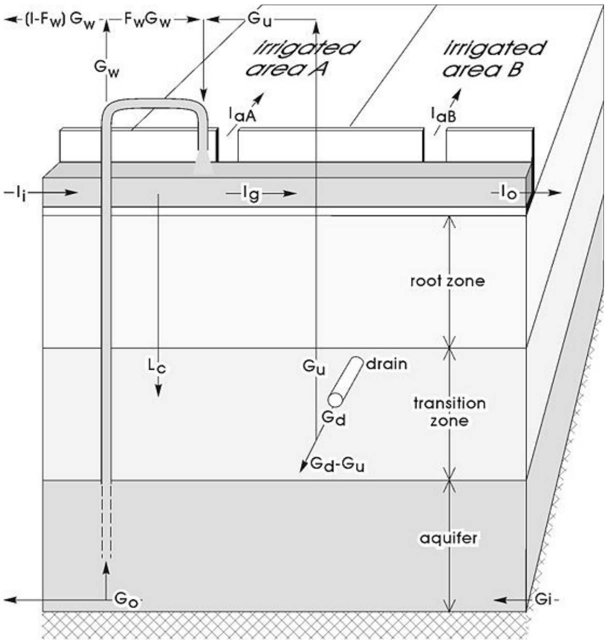
Horizontal hydrological components in the same zone with arrows in same direction can be combined into *excess values* .
For example : Egio = Iaq − Oaq (excess groundwater inflow over outflow), Egoi = Oaq − Iaq (excess groundwater outflow over inflow).

Salt balances

Agricultural water balances are also used in the salt balances of irrigated lands.

Further, the salt and water balances are used in agro-hydro-salinity-drainage models like Saltmod.

Equally, they are used in groundwater salinity models like SahysMod which is a spatial variation of SaltMod using a polygonal network.



Water balance components in the model *Saltmod*

Irrigation and drainage requirements

The *irrigation requirement* (Irr) can be calculated from the *topsoil water balance*, the *agronomic water balance* or the *overall water balance*, as defined in the section "Combined balances", depending on the availability of data on the water balance components.

Considering surface irrigation, assuming the evaporation of surface water is negligibly small (Eva = 0), setting the actual evapotranspiration Era equal to the potential evapotranspiration (Epo) so that Era = Epo and setting the surface inflow Isu equal to Irr so that Isu = Irr, the balances give respectively:

- Irr = Epo + Osu + Per − Rai − Cap
- Irr = Epo + Osu + Dtr + Dgw − Rai − Lca − Ugw
- Irr = Epo + Osu + Dtr + Oaq − Rai − Lca − Iaq

Defining the *irrigation efficiency* as IEFF = Epo/Irr, i.e. the fraction of the irrigation water that is consumed by the crop, it is found respectively that :

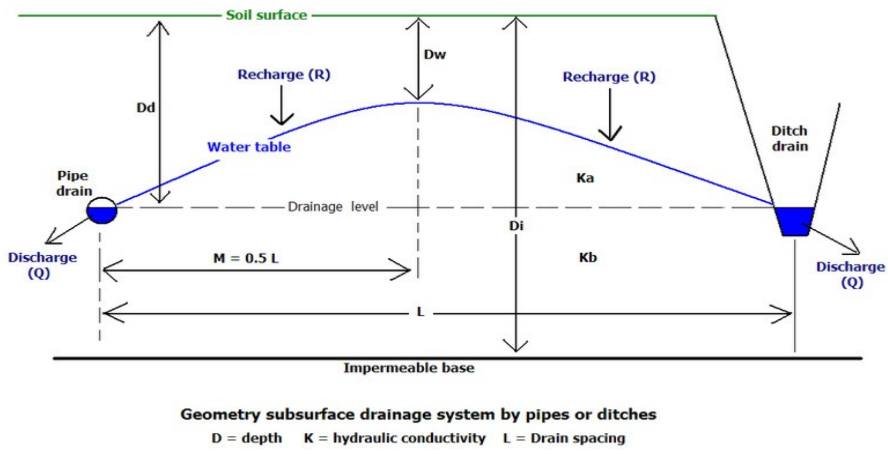
- IEFF = 1 − (Osu + Per − Rai − Cap) / Irr
- IEFF = 1 − (Osu + Dtr + Dgw − Rai − Lca − Ugw) / Irr
- IEFF = 1 − (Osu + Dtr + Oaq − Rai − Lca − Iaq) / Irr

Likewise the *safe yield* of wells, extracting water from the aquifer without overexploitation, can be determined using the *geohydrologic water balance* or the *overall water balance*, as defined in the section "Combined balances", depending on the availability of data on the water balance components.

Similarly, the subsurface drainage requirement can be found from the drain discharge (Dtr) in the *subsoil water balance*, the *agronomic water balance*, the *geohydrologic water balance* or the *overall water balance*.

In the same fashion, the well drainage requirement can be found from well discharge (Wel) in the *geohydrologic water balance* or the *overall water balance*.

The *subsurface drainage requirement* and *well drainage requirement* play an important role in the design of agricultural drainage systems.



The drain discharge determines the spacing between drains

References

1. N.A. de Ridder and J. Boonstra, 1994. *Analysis of Water Balances*. In: H.P.Ritzema (ed.), Drainage Principles and Applications, Publication 16, p.601-634. International Institute for Land Reclamation and Improvement (ILRI), Wageningen, The Netherlands. ISBN 90 70754 3 39

2. *Drainage for Agriculture: Hydrology and Water Balances*. Lecture notes, International Course on Land Drainage (ICLD), International Institute for Land Reclamation and Improvement (ILRI), Wageningen, The Netherlands. On the web : [1]

3. *SaltMod*, agro-hydro-salinity-drainage model

4. SahysMod, agro-hydro-salinity-drainage model combined with a polygonal groundwater flow model..

5. *The energy balance of groundwater flow applied to subsurface drainage in anisotropic soils by pipes or ditches with entrance resistance*. On the web : [2] . Paper based on: R.J. Oosterbaan, J. Boonstra and K.V.G.K. Rao, 1996, *The energy balance of groundwater flow*. Published in V.P.Singh and B.Kumar (eds.), Subsurface-Water Hydrology, p. 153-160, Vol.2 of Proceedings of the International Conference on Hydrology and Water Resources, New Delhi, India, 1993. Kluwer Academic Publishers, Dordrecht, The Netherlands. ISBN 978-0-7923-3651-8. On the web : [3]

6. Subsurface drainage by (tube)wells, 9 pp. *Well spacing equations for fully or partially penetrating wells in uniform or layered aquifers with or without entrance resistance*. International Institute for Land Reclamation and Improvement (ILRI), Wageningen, The Netherlands. On the web : [4]